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Powering a climate-neutral economy: An EU Strategy for Energy System Integration

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1. An integrated energy system for a climate-neutral Europe

The ambition of the Green Deal is to set Europe on track for the deep decarbonisation of all sectors of the economy, to achieve higher mitigation ambitions for 2030, and climate neutrality by 2050. The energy system is crucial to delivering on these goals. The recent decline in the cost of renewable energy technologies, the digitalisation of our economy and emerging technologies in batteries, heat pumps, or electric vehicles offer an opportunity to accelerate, over the next two decades, a profound transformation of our energy system and its structure. Europe's energy future must be more resource efficient, rely on an ever growing share of renewable energies, integrate different energy carriers flexibly and be further distributed across space.

Yet, today's energy system is still built on several parallel, vertical energy value chains, which rigidly link specific energy resources with specific end-use sectors. For instance, petroleum products are predominant in the transport sector and as feedstock for industry. In turn, coal and natural gas are mainly used to produce electricity and heating. Electricity and gas networks are planned and managed independently from each other. Market rules are also largely specific to different sectors. This model of separate silos is not suited for a climate neutral economy. It is also technically and economically inefficient and produces substantial losses in the form of waste heat and low energy efficiency.

Energy system integration – the coordinated planning and operation of the energy system "as a whole", across multiple energy carriers, infrastructures, and consumption sectors – is the pathway to an effective, affordable and deep decarbonisation of the European economy**.**

Declining costs for renewable energy technologies, market developments, rapid innovation regarding storage systems, electric vehicles, as well as digitalisation are all factors that naturally lead towards greater energy system integration in Europe. However, we have to go one step further and connect the missing links in the energy system in order to achieve higher decarbonisation objectives for 2030 and climate neutrality by 2050 – and do it in a cost effective way. Relying on greater use of clean and innovative processes and tools, the path towards system integration will also trigger new investments, jobs and growth. It can be a building block of the economic recovery in the aftermath of COVID-19 crisis and strengthen EU industrial leadership at a global level.

The Clean Energy Package, adopted in 2018, provides a basis for better integration across infrastructure, energy carriers and sectors; however, regulatory and practical barriers remain. Without robust policy action, the energy system of 2030 will be more akin to that of 2020 than a reflection of what is needed to achieve climate neutrality by 2050.

This Strategy sets out a **vision on how to accelerate the transition towards a more integrated energy system**, one that supports full decarbonisation at the least cost across sectors while promoting growth and technological innovation.

Turning this vision into a reality requires resolute action, now. Investments in energy infrastructure typically have an economic life of 20 to 60 years. The steps taken in the next five-to-ten years will be crucial for building an energy system that drives Europe towards climate neutrality in 2050.

Thus, this **Strategy proposes concrete policy and legislative measures at EU level to gradually shape a new integrated energy system**, while respecting the differing starting points of Member States. It contributes to the work of the Commission on a comprehensive plan to increase the EU 2030 climate target to at least 50% and towards 55% in a responsible way and identifies follow up proposals that will be prepared as part of the legislative reviews of June 2021, announced in the European Green Deal.

The parallel Communication on "*An EU Hydrogen Strategy*"[1] complements this Strategy to elaborate in more detail on the opportunities and necessary measures to scale up the uptake of hydrogen in the context of an integrated energy system.

2. ENERGY SYSTEM INTEGRATION AND ITS BENEFITS TO COST-EFFECTIVE DECARBONISATION

2.1. What is energy system integration?

Energy system integration refers to the planning and operating of the energy system "as a whole", across multiple energy carriers, infrastructures, and consumption sectors, by creating stronger links between themselves with the objective of delivering low-carbon, reliable and resource-efficient energy services, at the least possible cost for society. It encompasses three complementary and mutually reinforcing concepts.

First, a more "circular" energy system, with energy efficiency at its core, in which unavoidable waste streams are reused for energy purposes. This is happening already in combined heat and power plants or through the use of certain waste and residues[2]. There is however further potential, for example, in reusing waste heat from industrial processes, data centres, or energy produced from bio-waste or in wastewater treatment plants.

Second, a greater direct electrification of end-use sectors. The rapid growth and cost competitiveness of renewable electricity production allows to service a growing share of energy demand – for instance using heat pumps for space heating or low-temperature industrial processes, electric vehicles for transport, or electric furnaces in certain industries.

Third, the use of renewable and low-carbon fuels, including hydrogen[3], for end-use applications where direct heating or electrification are not feasible, not efficient or have higher costs. Here renewable gases and liquids produced from biomass, or hydrogen produced from renewable electricity can offer solutions. This also allows to store the energy produced from variable renewable sources, exploiting synergies between the electricity sector, gas

[1] Tittle to be decided. COM (2020) XXX final

sector and end-use sectors. Examples include using renewable hydrogen in industrial processes, synthetic liquid fuels produced from renewable electricity in aviation, or biomass in the sectors where it has the biggest added value.

A more integrated system will also be a "multi-directional" system in which consumers play an active role in energy supply. "Vertically," decentralised production units and customers contribute actively to the overall balance and flexibility of the system. For instance, biomethane produced from organic waste injected in gas networks at a local level, or "vehicle-to-grid" services. "Horizontally", exchanges of energy increasingly take place between consuming sectors. For instance, different energy customers should all contribute to a decarbonised energy system by exchanging heat in smart district heating and cooling systems, by feeding in renewable electricity or by reducing energy consumption according to demand.

2.2. What are the benefits of energy system integration?

System integration allows **decarbonising sectors that are more difficult to decarbonise**, for instance buildings, heavy-duty transport, maritime, aviation, or certain industrial processes, by using decarbonised energy like low-carbon electricity or renewable gases in combination with innovative demand side technologies. It ensures a most efficient use of energy sources, **reducing the amount of energy needed and related climate and environmental impacts**.

Electrification of certain end-use sectors can cut primary energy demand by a third[4] because of the efficiency of electrical end-use technologies. 29% of industrial energy demand dissipates as waste heat, which can be reduced or reused. Especially small- and medium size enterprises can create synergies by both improving energy efficiency and increasing the use of renewable resources and waste heat. The most efficient use of energy sources would reduce gross inland consumption by a third by 2050[5], whilst supporting an increase in GDP of 75%[6]. Beyond energy and greenhouse gases emissions savings, it would also reduce the energy water footprint[7], something essential for climate adaptation and to preserve natural resources.

Energy system integration will also **strengthen the competitiveness of the European economy** by promoting more efficient and new technologies and solutions across industrial ecosystems related to the energy transition, their standardisation and market uptake. Specialised enterprises will provide services locally and create more regional economic benefits. This creates an opportunity for the Union to maintain and leverage its leadership in smart grid technologies and district heating system and lead on a set of new, more efficient and complex technologies and processes that are expected to play a growing role in the energy systems worldwide such as batteries or hydrogen technologies.

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[4] Electric vehicles have an efficiency of around 60% compared to 20% for combustion engines, and heat pumps can deliver heat with three times less energy input than boilers.

[5] See LTS figure 18: -21% in the 1.5TECH and -32% in the 1.5LIFE; but as deep as -40% in the EE scenario

[6] See LTS figure 92: 2050 GDP between 166% and 174% of 2015 or between GDP 154% and 161% of 2020 GDP.

[7] For instance, the water footprint of EU energy production was in 2015 198 km^3 or 1068 litres per person and per day, or 242 km^3 or 1301 litres per person and per day including energy imports.

Moreover, better integration will **provide additional flexibility** for the overall management of the energy system and thus to successfully integrate increased shares of variable renewable energy production. This will also boost **storage technologies**: pumped hydropower, grid-scale batteries and electrolysers provide flexibility in the electricity sector. Home batteries and electric vehicles ('behind-the-meter') in buildings can help manage better the distribution grids. By 2050, electric vehicles could provide up to 20% of the flexibility required on a daily basis[8,] Thermal storage at factory-level can provide flexibility in the industrial sector. Through the closer integration of the power and heat sector, electric heat appliances could already make use of real time electricity prices to smarten demand response. Hybrid heat pumps[9] and smart district heating also provide opportunities for arbitrage between electricity and gas markets. Moreover, electrolysers can transform renewable electricity into renewable hydrogen, providing long-term storage and buffering capability, and further integrating the electricity and gases markets[10].

Finally, by linking up the different energy carriers and through localised production and smart use of distributed energy supply, system integration can also contribute to **greater consumer empowerment, improved resilience and security of supply.** Replacing imported natural gas and petroleum products with locally produced renewable electricity, gases and liquids will reduce the import bill and create a more resilient European economy.

3. MAKING IT HAPPEN - AN ACTION PLAN TO ACCELERATE THE CLEAN ENERGY TRANSITION THROUGH ENERGY SYSTEM INTEGRATION

The strategy identifies five pillars where coordinated measures are outlined to address existing barriers for energy system integration.

3.1. A more circular energy system, with "energy-efficiency-first" at its core

Mainstreaming the energy-efficiency-first principle across sectoral policies is at the core of system integration. Energy efficiency reduces the investments needs and costs associated with energy production, infrastructure and use. It also reduces the related land and material resources use, and associated pollution and biodiversity losses. At the same time, system integration can help Europe achieve greater energy efficiency, through a more circular use of available resources and by switching to more efficient energy technologies. For instance, electric vehicles show much higher energy efficiency than combustion engines; and replacing a fossil-fuel based boiler with a heat pump using renewable electricity saves two thirds of primary energy.[11]

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[8] According to METIS-2 S6 baseline 19% (186TWh of 951TWh of total daily flexibility needs) would be provided by e-vehicles

[9] Heat pumps coupled with a boiler

[10] Either directly as hydrogen or with additional steps as Methane, Ammonia, or in other forms.

[11] Source

The first challenge is to **apply the energy-efficiency-first principle consistently across the whole energy system**. This includes giving priority to demand-side solutions whenever they are more cost effective than investments in energy supply infrastructure in meeting policy objectives, but also properly factoring in energy efficiency in generation adequacy assessments. The Energy Efficiency Directive and Energy Performance of Buildings Directive already provide incentives for customers, but not enough for the full supply chain. Further measures are needed to ensure that customers' decisions to save, switch or share energy **properly reflect the life cycle energy use** of the different energy carriers, including extraction, production and reuse or recycling of raw materials, conversion, transformation, transportation and storage of energy, and the growing share of renewables in electricity supply.

The **Primary Energy Factor** (PEF)[12] is an important tool to facilitate comparisons of savings across energy carriers. Most renewables are 100% efficient and have a low PEF. The PEF should reflect the real savings brought about by renewable electricity and heat. The Commission will review the level of the PEF and assess whether current provisions in EU legislation ensure an adequate application of the PEF by Member States.

The upcoming '**Renovation Wave**' initiative, announced in the European Green Deal, will also propose concrete actions to accelerate the uptake of energy and resource efficiency measures and of renewables in buildings across Europe in the next few years.

The second challenge is that **local energy sources are insufficiently or not effectively used in our buildings and communities**. Applying the principle of circularity in line with the new Circular Economy Action Plan[13], a big, yet largely unused potential is the reuse of **waste heat** from industrial sites, data centres, supermarkets or other sources. Energy reuse can take place on-site (for example through the re-integration of process heat within manufacturing plants) or via a district heating and cooling network. The Energy Efficiency and Renewable Energy Directives already contain provisions targeting this potential, but there is a need to further strengthen the regulatory framework to lift barriers hampering the wider application of these solutions. These barriers include insufficient awareness and knowledge about these solutions, the reluctance of companies to enter into a new business that is not their core activity, a lack of regulatory and contractual frameworks to share the costs and benefits of new investments, and barriers related to planning, transaction costs, and pricing signals. As regards data centres specifically, the Digital Strategy and the Circular Economy Action Plan[14] have announced the ambition to make them climate-neutral and highly energy-efficient by no later than 2030; a greater re-use of their waste heat will significantly contribute to that objective.

[12] The primary energy factor indicates the amount of primary energy used to generate a unit of final energy (electrical or thermal), allowing a comparison of the primary energy consumption of products with the same functionality using different energy carriers. It shall be revised periodically according to Annex IV EED.

[13] Reference

[14] Reference

A third challenge is linked to the untapped use of **wastewater**[15] **and biological waste and residues for bioenergy production**, including biogas. Biogas can be exploited on-site to reduce fossil fuel consumption, or upgraded to biomethane to allow injection into the natural gas grid. Also, some farm infrastructures are suitable for an integrated production of solar-origin electricity and heat, creating the potential for renewable energy self-consumption and injection into the grid. The implementation of the Circular Economy Action Plan and sustainable agriculture and forestry management systems could result in increased sustainable production of bioenergy from wastewater, waste and residues[16], while other forms of bioenergy will remain limited due to sustainability or pollution concerns[17]. More efforts are needed to take advantage of the full potential for energy system integration, exploiting synergies and avoiding trade-offs, and notably financing, through the Common Agriculture Policy, could incentivise farmers to contribute to a greater mobilisation of sustainable biomass for energy. Renewable energy communities can provide a sound framework for the use of such energy in a local context.

Key actions

To better enshrine the energy-efficiency-first principle:

- Issue **guidance** to Member States on how to **make the energy-efficiency-first (EEF) principle operational** across the energy system in application of EU and national legislation (by 2021).
- **Further promote** the EEF principle in the elaboration of upcoming relevant methodologies (e.g. in the context of the European resource adequacy assessment) and legislative revisions (e.g. TEN-E).
- Anticipate the update of the default value of the **Primary Energy Factor**, in order to fully recognise energy efficiency savings via renewable electricity and heat, as part of the review of the Energy Efficiency Directive (June 2021).

To build a more circular energy system:

- Facilitate the **reuse of waste heat from industrial sites and data centres,** through strengthened requirements for connection to district heating networks, energy performance accounting and contractual frameworks, as part of the revision of the Renewable Energy Directive and Energy Efficiency Directive (June 2021).
- Incentivise the **mobilisation of biological waste and residues from agriculture**, **food and forestry** sectors, through "eco-schemes" and the rural development pillar of the new Common Agriculture Policy, and support capacity-building for **rural circular energy communities** through the new LIFE programme (from 2021 onwards).

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[15] Wastewater treatment plants represent almost 1% of electricity consumption in Europe. This consumption can be reduced with more efficient technologies, and energy can be better recovered from those plants.

[16] The overall potential for increased biogas production from waste and residues remains high and, if fully exploited, could lead to biogas and biomethane production levels in 2030 of 2.7–3.7% of the EU's energy consumption in 2030 (link Commission study)

[17] Such as food and feed crop based biofuels, in line with the provisions of the recast Renewable Energy Directive, or waste incineration not respective the waste hierarchy.

3.2. Accelerating the electrification of energy demand, building on a largely renewables-based power system

Electricity demand is projected to increase significantly on a pathway towards climate neutrality, with the share of electricity in final energy consumption growing from 23% today to around 25% in 2030, and towards 40-50% by 2050[18]. In comparison, that share has only increased by 5 percentage points over the last thirty years.

This growing electricity demand will have to be largely based on renewable energy. By 2030, the share of renewable energy in the electricity mix should double[19], and projections show a share in the range of 80% to 85%[20] by 2050. Despite continuous cost reductions in renewable power generation technologies, economic drivers alone are unlikely to be sufficient to meet the massive need for more renewable power. Existing barriers include underdeveloped supply chains, the need for more grid infrastructure at national and cross-border level, the lack of public acceptance, administrative barriers and lengthy permitting (including for repowering), financing, the need for public or private long term hedging options, or high costs for some less mature technologies.

The need for increased electricity supply can be, among others, met by off-shore renewable energy production. The potential of off-shore renewable energy in the EU is between 220-440 GW by 2050[21], against today's capacity of some 20 GW. This represents a huge opportunity for the EU industry to become number one in off-shore technology, but will require considerable efforts to increase the European industrial capacity and build the new value chains. Offshore electricity production also creates an opportunity for the nearby localisation of electrolysers for hydrogen production, including the possible reuse of the existing infrastructure of depleted natural gas fields. The development of solar energy will also receive constant attention.

On the demand side, certain incentives to electrification are provided through the sectoral targets set out in the Renewable Energy Directive. But challenges for **increased electrification remain and differ per sector**.

In **buildings,** renewable electricity is expected to play a central role, in particular through the roll-out of heat pumps for space heating and cooling. In the residential sector, the share of electricity in heating demand should grow to 40% by 2030 and to 50-70% by 2050; in the services sector, these shares are expected to be around 65% by 2030 and 80% by 2050[22]. Large-scale heat pumps will play a relevant role in district heating and cooling. The most important barrier is the relatively higher level of taxes and levies applied to the electricity, and the lower levels of taxation for fossil fuels (oil, gas and coal) used in the heating sector, leading to lack of level playing field. Progress is also hampered by a number of other barriers,

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[18] Source

[19] [Add figures and LTS source]

[20] LTS: Between 81 and 85% with 83% average over LTS scenarios, according to figure 23 in the LTS

[21] LTS data

[22] LTS Figure 42

including unfit infrastructure planning, building codes and products standards, lack of skilled workforce for installation and maintenance, lack of public and private financing instruments, and lack of internalisation of CO2 costs in heating fuels. This translates into low replacement rates of the EU fossil heating stocks, low development and modernisation of district heating/ cooling networks, and low building refurbishment rates. With the Renovation Wave initiative, the Commission will ensure a higher penetration of renewables in buildings.

In **industry**, heat represents more than 60% of energy use. Industrial heat pumps can help decarbonise the low temperature heat supply within industries, and can be coupled with waste heat recovery. Other technologies are being developed for higher temperature heating (such as microwave or ultrasound) and for electrifying processes by electrochemistry. Barriers to deployment include lack of information and long pay-back, due to the high price of electricity relative to gas and the high abatement cost associated with these technologies, relative to current CO2 prices. Changes in the production process leading to higher costs could also affect the competitiveness of sectors exposed to international competition. EU support could help develop a number of flagship projects and demonstrate innovative electricity-based processes. Furthermore, the industrial supply chain for these technologies is not sufficiently mature and the integration of these electrification technologies into industrial processes requires training and new skills. This could be addressed, for instance, with a Heat Pump Alliance, a Heat Network Alliance, and targeted Skill Alliances and training programmes.

In **transport**[23], electric mobility will change our cities, and new mobility services will increase the efficiency of the transport system. The share of electric passenger vehicles in total vehicles is expected to increase from around 7% in 2030 to between 50-75% by 2050[24]. Rapidly falling cost of electric cars means that they could be competitive with combustion engine vehicles around 2025, on a total cost of ownership basis[25]. The Commission's ambition is to roll-out the necessary charging infrastructure, starting with [2) million public charging stations by 2025. To that end the Commission will mobilise InvestEU and Connecting Europe Facility funding to broaden the coverage of the charging infrastructure network, and revise the Alternative Fuels Infrastructure Directive. The Commission will also tackle challenges such as range anxiety, insufficient recharging infrastructure, still high upfront costs relative to combustion cars, the non-transparent pricing at public charging stations and the persistent lack of cross-border interoperability of charging services, which continues to hinder the deployment of this technology. Measures are also needed to facilitate the electrification of road freight transport.

Electrification can present challenges for the management of the electricity system. Regional and cross-border coordination between Member States will become increasingly important. This will be addressed by the development of Regional Coordination Centres[26] in 2022, allowing for more robust security analysis, emergency and outage coordination and common infrastructure planning, and the deployment of storage and other flexibility options.

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23 Including mobile machinery

24 LTS Figure 45

25 Add source

26 ADD reference in Electricity Regulation

The Commission will support the **uptake of energy storage** through full implementation of the Clean Energy Package and in the upcoming legislative reviews, including the TEN-E review.

Challenges are also expected at a more local level. For instance, the full electrification of passenger road transport could lead to an increase in electricity demand by 20 – 25%[27]. At the same time, it can create **opportunities for providing storage and flexibility** to the system[28]. In particular, **smart charging** and so-called **Vehicle-to-Grid** (V2G) services will be essential to manage grid congestion and limit costly investments into grid capacity. The Electricity Directive contains a number of provisions that lay the basis for enabling smart charging and the development of V2G services, but challenges still remain, for instance regarding the deployment of smart recharging points, standards and communication protocols, grid charges, taxation and access to the in-vehicle data. The Network Code on Demand Side Flexibility as well as the review of the Alternative Fuels Infrastructure Directive both represent opportunities to create a robust framework for the successful integration of demand-side flexibility in general, and EVs in particular.

[27] See JRC Science for Policy Report, 2018, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC112745/jrc112745_kjna29401enn.pdf

[28] See Study on energy storage – Contribution to the security of the electricity supply in Europe, 2020

Key actions

To ensure continued growth in the supply of renewable electricity:

- Increase the supply of **off-shore renewable electricity and strengthen EU's industrial leadership** through the Offshore Renewable Strategy (2020) and related regulatory and financing follow-up actions.
- As part of the **Renovation Wave** initiative, promote the further electrification of buildings' heating (in particular through heat pumps), the deployment of on-buildings solar energy, and the roll-out of EV charging points (from 2021 onwards).
- Explore minimum **mandatory green public procurement** (GPP) criteria and targets in relation to **renewable electricity**, possibly as part of the revision of the Renewable Energy Directive (June 2021), supported by **capacity building** financing under the LIFE programme.

To further accelerate the electrification of energy consumption:

- Develop more specific measures for the use of **renewable electricity in transport**, as well as for **heating and cooling** in buildings and industry, building on the sectorial targets of the Renewable Energy Directive (June 2021).
- Finance pilot projects for the **electrification of low-temperature process heat in industrial sectors** through Horizon Europe and the Innovation Fund (by 2021).
- Assess options for further promoting the electrification of industrial processes in the review of the **Industrial Emissions Directive**, including the integration of electrification practices in upcoming Best Available Techniques reference documents (2021).

To accelerate the roll-out of EV infrastructure and ensure the integration of new loads:

- **Revise the Alternative Fuels Infrastructure Directive** to accelerate the roll-out of the alternative fuels infrastructure, including for EVs, strengthen interoperability requirements, ensure adequate customer information, cross-border usability of charging infrastructure, and the efficient integration of EVs in the electricity system (by 2021). Take up corresponding requirements for charging and refuelling infrastructure in the **revised Regulation for the Trans-European Transport network (TEN-T)** (by 2021).
- Develop a **Network Code on Demand Side Flexibility** (by 2021) to unlock the potential of EVs, heat pumps and other electricity consumption to contribute to the flexibility of the energy system.

3.3. Promote renewable and low-carbon fuels, including hydrogen, for hard-to-decarbonise sectors

While direct electrification and renewable heat present the most cost-effective decarbonisation options in many cases, there are a number of end-use applications where direct renewable heating or electrification might not be feasible or have higher costs. In such cases, a number of renewable or low-carbon fuels could be used, such as biogas and biomethane, biofuels, renewable and low-carbon hydrogen or synthetic fuels.

Unlocking the potential of renewable fuels produced from biomass

Today, **biofuels and biogases** account for only 3.5% of all gases and fuels consumption[29] and are largely based on food and feed crops. Their full potential should be achieved in a sustainable manner, which mitigates both climate and biodiversity risks [30].

Biofuels are *liquid* fuels produced from biomass, through a variety of processes and using a variety of feedstock, such as biodiesel, bioethanol and Hydrotreated Vegetable Oils (HVO). **Biogas** is a *gaseous* mixture (primarily methane and carbon dioxide) produced from biomass, through the decomposition of organic matter in the absence of oxygen (anaerobically). Biogas can be used directly as a fuel, or be purified or "upgraded" into **biomethane,** which can thus be used for the same applications as natural gas and injected into the gas grid.

The use of "advanced" biofuels and biogas (gained from certain residues and by-products from agriculture and forestry activities, industrial and municipal waste, and other ligno-cellulosic material) is encouraged under the Renewable Energy Directive. Biofuels and biogas need to meet certain sustainability requirements to be statistically accounted as renewable under the Renewable Directive.

Biofuels will have an important role to play, mainly in hard-to-decarbonise transport modes, such as aviation or maritime – including through hybridisation projects linking biofuels and renewable hydrogen production[31]. Biomethane can contribute to the decarbonisation of the gas supply. The deployment of biofuels and biogases has been hampered by regulatory uncertainty and lack of targeted support. The revised Renewable Energy Directive has taken a first step to address these issues by introducing a target of 3.5% for the consumption of advanced biofuels and biogas in transport. Its revision, as well as the upcoming initiatives on Sustainable Aviation and Maritime Fuels (Refuel Aviation and FuelMaritime) could be used as a lever for further targeted support for the take-up of such fuels. In addition, the Communication *The role of Waste to Energy in the circular economy*[32] clarifies which waste-to-energy approaches are more sustainable, including for the production of biomethane, while the Biodiversity Strategy underlines that the use of whole trees and food and feed crops for energy production should be minimised.

Promoting the use of renewable hydrogen in hard-to-decarbonise sectors

Today, hydrogen contributes less than 1 percent of Europe's energy consumption[33], and is almost exclusively produced from unabated fossil fuels. Hydrogen has an important role to

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[29] Eurostat

[30] This is why the recast Renewable Energy Directive establishes a cap to first generation biofuels and limitations to high Indirect Land Use Change (ILUC) risk food and feedstocks, while reinforcing and extending sustainability criteria

[31] Add example

[32] COM (2017) 034 final

[33] FCHJI (2019) Hydrogen roadmap

play in reducing emissions in hard-to-decarbonise sectors, in particular as a fuel in certain transport applications (heavy-duty freight, captive fleets of buses and taxis, or non-electrified rail transport) and as a fuel or feedstock in certain industrial processes (steel, refining or chemical industries – including in the production of "green fertilisers" for agriculture). Hydrogen can also be further transformed into synthetic fuels, such as synthetic kerosene in aviation.

Hydrogen produced through electrolysis using renewable electricity can play a particularly important "nodal" role in an integrated energy system. Indeed, it can help integrate large shares of variable renewable generation, by offloading grids in times of abundant supply, and providing long term storage to the energy system, and allow local renewable electricity production to be used in a range of additional end-use applications.

The [Hydrogen Strategy], published today, presents specific measures to create the conditions for hydrogen to contribute to decarbonising our economy in a cost-effective way, addressing the whole hydrogen value chain to support economic growth and recovery[34]. While the priority is to deploy renewable hydrogen, due to its specific benefits, low-carbon hydrogen can also play a role in a transitory period. In addition to providing financial assistance supporting wider use of hydrogen in such end-use applications, the Commission will consider establishing minimum shares or quotas of renewable hydrogen in specific end-use sectors. Renewable and low-carbon fuels (including hydrogen)[35] can be promoted most effectively if they can be easily distinguished from more polluting energy sources. Therefore, the Commission will develop a comprehensive terminology and a European certification system covering all renewable and low carbon fuels. Such system, based notably on stringent greenhouse gas performance criteria, will allow for more informed choices when deciding on policy options at the EU or national level.

Enabling carbon capture, storage and use to support deep decarbonisation, including synthetic fuels

Even a fully integrated energy system cannot completely eliminate CO2 emissions from all parts of the economy. Together with alternative process technologies**, carbon capture and storage** (CCS) is likely to play a role in a climate-neutral energy system, in particular addressing hard to abate emissions **in certain industrial processes** with large process emissions, thus enabling these industries to have a place in a climate neutral economy and maintaining industrial jobs in Europe. When stored, such CO2 captured from biogenic sources or direct from the atmosphere could even compensate residual emissions in other sectors.

An alternative to the permanent storage of CO2, is its use combining the CO2 with renewable hydrogen to produce synthetic gases, fuels and feedstock (CCU). Synthetic fuels can be associated with very different levels of greenhouse gas emissions depending on the origin of CO2 (fossil, biogenic, or captured from the air), and the process used. Full Carbon-neutral synthetic fuels require sourcing the CO2 from biomass or the atmosphere. While synthetic

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[34] Renewable hydrogen refers to hydrogen produced in electrolysers powered by renewable electricity; hydrogen produced through the reforming of biomethane (sometimes combined with carbon capture); or through the pyrolysis of biomass.

[35] For the definition of low-carbon hydrogen see [the Hydrogen Strategy]

fuels are currently associated with a high energy and cost penalty, it is important to make clear progress in their development early on as they can become a substitute for fossil fuels in particular in the most difficult sectors to decarbonise, such as aviation.

It is of key importance to properly monitor, report and account the emissions and removals of CO2 associated with the production of synthetic fuels to reflect correctly their actual carbon footprint. Complementing the current GHG emission monitoring and reporting system [36]with a robust carbon removal certification mechanism will allow the tracking of the CO2 fluxes involved in CCU processes such as the production of synthetic fuels and therefore offer traceability of the CO2 along its emission, capture, use and potential reemission throughout our economic system. A carbon removal certification can allow to provide regulatory incentives for market take-up of synthetic fuels.

The uptake of CO2 capture and usage in Europe is slow, with investment and operational costs are still high. There are also barriers that prevent the transport of CO2 to those places where it will be stored or used. In some parts of the EU, there are also objections among citizens and political decision-makers regarding the storage of CO2. An annual European CCUS Forum could be convened as part of the Clean Energy Industrial Forum to further study options to foster CCUS projects.

Key actions

- Propose a **comprehensive terminology for all renewable and low-carbon fuels** and a **European system of certification** of such fuels, based notably on GHG emission savings and sustainability criteria, building on existing provisions of the Renewable Energy Directive (June 2021).
- Assess the need for **additional measures to support renewable and low-carbon fuels,** possibly through minimum shares or quotas in specific end-use sectors (including aviation and maritime), building on sectoral targets set in the Renewable Energy Directive (June 2021).
- Exploring the opportunities that the REFUEL aviation and FUEL maritime initiatives could provide **to support renewable and low-carbon fuels**.
- Promote the financing of **flagship projects** of **integrated, carbon-neutral industrial clusters** producing and consuming renewable and low-carbon fuels, through LIFE, Horizon Europe, and InvestEU (from 2021).
- Stimulate first-of-a-kind production of **green fertilisers** through Horizon Europe and support its scale up through Member States eco-schemes (from 2021).
- Demonstrate and scale-up the **capture of carbon** for its use in the production of **synthetic fuels**, possibly through the Innovation Fund (from 2021).
- Develop a regulatory framework for the **certification of carbon removals** based on robust and transparent carbon accounting to monitor and verify the authenticity of carbon removals (by 2023).

[36] Reference to EU GHG monitoring GHG system and ETS MRV

3.4. Making energy markets fit for decarbonisation and distributed resources

In an integrated energy system, trustworthy and efficient markets should guide customers to rely on the most efficient and cheapest decarbonisation option. Markets also should send clear signals and help allocating the different renewable energy supply options to the different end-sectors based on their decarbonisation needs. Functioning markets and the internalisation of costs into the prices of energy carriers are also a prerequisite for taking energy-efficient decisions, allowing full consideration of demand-side options as alternatives to supply side options.

Non-energy price components across energy carriers should contribute to decarbonisation

In many EU Member States, **taxes and levies on electricity are higher**, both in absolute value and as a share of total price[37], than for coal, gas or heating oil. Over the past years, charges, taxes and levies on electricity, such as those financing renewable support schemes, continued to increase. At the same time, the *energy component* of the final (retail) electricity price[38] has reduced both in absolute and relative terms. This has widened the asymmetry in non-energy costs between electricity and gas: for retail household electricity prices, for instance, taxes and levies made up 40% compared to 26% of gas or 32% for heating oil. Some other energy- or carbon-intensive sectors such as international aviation and maritime transport, as well as agriculture, can be subject to low or no VAT and energy excise duties under the current Energy Taxation Directive.

The specificities of electricity consumed for energy storage or hydrogen production should also be considered when implementing the Clean Energy Package rules, avoiding double taxation where applied, so that energy is only taxed when existing the energy system, and double grid charges where they are not justified.

Finally, carbon costs are partially or not internalised at all in some sectors (e.g. road transport, maritime navigation or space heating), or may not be sufficient to incentivise decarbonisation in some sectors covered by ETS (e.g. aviation). Fossil fuel subsidies still persist in the EU.

Placing consumers at the centre

Clear and easily accessible information is essential for enabling citizens to change energy consumption patterns and switch to energy integration solutions[39]. Customers – citizens and businesses alike – should be provided with information on their rights and on the technology options available to them. Only then, they can select and invest in goods and services, from which they can benefit the most and become true drivers of decarbonisation. In the context of the Climate Pact, the Commission will launch a **consumer information campaign** on their rights related to the energy market. Customer information rights for electricity customers have been enhanced with the Clean Energy Package – further work remains to be done for gas and district heating customers to align those with the electricity sector.

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[37] Add source

[38] made up by the wholesale price and the service costs from electricity suppliers

[39] Reference to Eurobarometer

Furthermore, markets for sustainable products and services produced from renewable and low-carbon fuels are still missing, and consumers do not receive relevant information that may encourage them to pay a price premium and thus incentivise investments into more sustainable.

Making electricity and gas markets fit for decarbonisation[40]

The Clean Energy for all Europeans package lays down the foundation for **electricity markets** fit for the integration of large amounts of variable electricity and the integration of flexibility from demand response and storage, while improving the market signals to stimulate investments and empowering electricity customers. The challenge now lies in the proper implementation of the measures, in particular the completion of market coupling through day-ahead and intraday trading. At national level, market reforms also need to be carried out before considering implementing capacity mechanisms.

As we progress towards climate-neutrality, the volume of natural gas consumed in Europe will progressively reduce. While **gaseous fuels** are expected to continue to play an important role in our energy mix,[41] their share highly depends on the chosen decarbonisation pathway. By 2050, the share of natural gas in gaseous fuels is estimated to reduce to 20%, and the bulk of the remaining 80% gaseous fuels should be of renewable origin[42]. However, the future mix of these gaseous energy carriers – hydrogen, biomethane, or synthetic gases – is hard to foresee.

The gas market regulatory framework should be re-examined so as to facilitate the uptake of renewable gases, empowerment of customers, whilst ensuring an integrated, liquid and interoperable EU internal gas market.

In this context, the areas to look at include the connection to infrastructure and the market access for distributed production of renewable gases, including at the distribution level, which would complement the use of renewable gases in a more local, circular context (such as biogas used on farm). To the extent that renewable gases are injected into the gas network and supply sources are further diversified, the parameters of gas consumed and transported in the EU would change. To avoid this leading to market segmentation and trade restrictions, there is a need to look at how to ensure the interoperability across gas systems and the unhindered flow of gases across the borders of the Member States. Furthermore, short-term trading should be facilitated.

Updating the State aid framework

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[40] Issues connected to the creation of open and competitive markets for hydrogen are covered in the dedicated Hydrogen Strategy

[41] The LTS 1.5TECH and LTS 1.5LIFE scenarios projects a share of 18-22% in the EU energy mix by 2050, compared to 25% today.

[42] A Clean Planet for all. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. In-depth analysis in support of the Commission communication COM(2018) 773.

The current review of the State aid framework and the corresponding provisions in the General Block Exemption Regulation will be taken as an opportunity to address market barriers to the deployment of clean energy[43].

Key actions

To ensure a more level-playing field across all energy carriers:

- **Issue guidance to Member States** to address the high charges and levies borne by electricity and to ensure the **consistency of non-energy price components across energy carriers** (by 2021).
- Align the taxation of energy products and electricity with EU environment and climate policies, and ensure a harmonised taxation of both storage and hydrogen production, avoiding double taxation, through the **revision of the Energy Taxation Directive**.
- Provide more consistent carbon price signals across energy sectors (including through a **possible proposal for the extension of the ETS to new sectors**) (by June 2021).
- Further work towards the **phasing out of direct fossil fuel subsidies,** including in the context of review of the State aid framework and the revision of the Energy Taxation Directive (from 2021 onwards).
- Ensure that the revision of the **State aid framework** supports cost-effective decarbonisation of the economy where public support remains necessary (by 2021).

To adapt the gas regulatory framework to the uptake of renewable gases:

- **Review the gas legislative framework to design a competitive decarbonised gas market,** fit for renewable gases, **including to empower gas customers** with enhanced information and rights (by 2021).

To improve customer information:

- **Review the district heating legislative framework to district heating customers** with enhanced information and rights (by 2021).
- **Improve information to customers on the sustainability of industrial products** (in particular steel, cement and chemicals) as part of the sustainable product policy initiative, and, as appropriate, through complementary legislative proposals (by 2022).

3.5. A more integrated energy infrastructure

System integration will translate into more physical links *between* energy carriers. This calls for a **new, holistic approach for both large-scale and local infrastructure planning**. The objective should be to make the most of the existing infrastructure while avoiding both lock-in effects and stranded assets. Infrastructure planning should facilitate the integration of various energy carriers and arbitrate between the development of new infrastructure or re-purposing of existing ones. It should consider alternatives to network-based options, especially demand-side solutions and storage. It should be informed by the National Energy and Climate Plans and, to the extent feasible, the local conditions.

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[43] Beyond those provisions, the Research, Development and Innovation Framework and the Communication setting out criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest are also relevant.

Modern low-temperature **district heating systems**[44] can connect local demand with renewable and waste energy sources, as well as the wider electric and gas grid – contributing to the optimisation of supply and demand across energy carriers. However, district heating networks account for 12% of the total final heating and cooling energy consumption, are highly concentrated in a few Member States, and only a limited share of them are highly efficient and based on renewables.

The Clean Energy Package will ensure an efficient use of **electricity grids**. Nevertheless, accelerated electrification of new end-uses will require smartening and grid reinforcement, mainly at distribution but also at transmission level. Electrolysers will link up to the electricity grids, and possibly gas grids.

The existing **gas network** provides ample capacities across the EU to integrate renewable and low-carbon gases and repurposing gas network for hydrogen applications may provide in some cases a cost-efficient solution, including to transport renewable hydrogen from offshore renewable electricity parks. Ports could transform into centres for offshore electricity, enable global trade of renewable hydrogen or synthetic fuels, and with LNG terminals ready to receive liquid hydrogen.

While gas networks may be used[45] to enable blending of hydrogen to a limited extent during a transitional phase, **dedicated infrastructures for large-scale storage and transportation of pure hydrogen**, going beyond point-to-point pipelines within industrial clusters, and the expansion of hydrogen refuelling stations[46] may need to be developed.

Similarly, further reflection is needed on the role of **CO2-dedicated infrastructure,** transporting CO2 across industrial sites for further use, or to large scale storage facilities.

The Regulation on Trans-European Networks in Energy (TEN-E) provides a framework for the selection of infrastructure projects of common interest in electricity, gas and CO2 networks. In this context, currently, 10-Year Network Development Plans (TYNDPs) at national and EU level are developed in parallel for gas and electricity by Transmission System Operators. Future network planning will require a more integrated and cross-sectoral approach, notably of the electricity and gas sectors, full consistency with climate and energy targets, including alignment with NECPs, and adequate consideration of all relevant actors.

The Commission will ensure that the ongoing revision of the TEN-E Regulation makes it fully consistent with climate neutrality and enables the cost-effective integration of the energy system and a synergetic integration with digital and transport. The ongoing revision of the Regulation on the Trans-European Transport network (TEN-T) seeks synergies with the TEN-E, aiming to generate additional opportunities for the decarbonisation of transport by drawing benefits from the new vision of energy infrastructure planning.

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[44] So-called 4th generation district heating systems

[45] A blend of 5-20% by volume can be tolerated by most systems without the need for major infrastructure upgrades or end-use appliance retrofits or replacements (BNEF, 2020).

[46] 750 hydrogen refuelling stations are being planned or announced before 2025 (HFCJU, 2019)

Key actions

- **Revise the TEN-E and TEN-T regulations** (by 2020 and 2021, respectively), to ensure that they fully support a more integrated energy system – including through greater synergies between the energy and transport infrastructure.
- **Review the scope and governance of the TYNDP** to ensure full consistency with the EU's decarbonisation objectives and cross-sectoral infrastructure planning (by 2021).
- Accelerate investment in **smart, highly-efficient, renewables-based district heating and cooling networks**, if appropriate through stronger obligations in legislation (e.g. revision of the Renewable Energy Directive and Energy Efficiency Directive) (June 2021) and through the financing of flagship projects.

3.6. A digitalised energy system and a supportive innovation framework

Digitalisation can enable dynamic and interlinked flows of energy carriers, allow for more diverse markets to be connected with another, and provide the necessary data to match demand and supply at a more disaggregated level and close to real time. A combination of novel sensors, advanced data exchange infrastructures, and data handling capabilities that make use of Big Data, Artificial Intelligence, 5G and distributed ledger technologies can enhance forecasting, allow the remote monitoring and management of distributed generation and improve asset optimisation, including the on-site use of self-generation.

Digitalisation is also key to unleash the full potential of customers with flexible energy consumption across different sectors to contribute to the efficient integration of more renewables. This requires an upgraded **market design for digital services** based on interoperability across different energy and non-energy sectors, a non-discriminatory and transparent access to data and its governance under an EU data framework.

At the same time, digitalisation must be supported by new technological developments and an **upgrade of skills** of energy companies, active customers and public administration. It provides an opportunity for economic growth and worldwide **technological leadership**.

Digitalisation represents itself a challenge in terms of **increasing energy demand** for ICT equipment, networks and services which needs to be adequately managed in the context of an integrated energy system. Digitalisation also brings other challenges for the energy sector, in particular on **ethics, privacy and cybersecurity** considerations tailored-made to the specificity of the energy sector. For example, a coordinated and simultaneous cyber-attack against 137.000 electric vehicles could create power imbalances of the continental grid that could be sufficient to create a black-out[47].

A supportive research and innovation framework

[47] Source

R&I will be a key enabler to creating and exploiting new synergies in the energy system, being in relation to e-mobility, to heating or to decarbonisation of energy intensive industries by integrating renewables and by increasing overall system efficiency. The research focus should be on enabling lower maturity technologies to come into the market, while more mature and innovative technologies to be up scaled through large scale demonstrations using complementarities amongst the various EU funding programmes.

Key actions

- **Adopt a Digitalisation of Energy Action plan** by 2021 to develop a competitive market for digital energy services that ensures data privacy and sovereignty.
- Develop a Network Code on **cybersecurity in electricity** (by end 2021).
- Publish an **impact oriented clean energy R&I outlook** for the EU to ensure R&I supports energy system integration (by end 2020).

4. CONCLUSIONS

This communication sets out a vision for how energy system integration can contribute to the energy system of the future. That is, one that is resilient, secure and driven by the twin goals of a cleaner planet and a stronger economy for all.

The transition to a more integrated energy system is of crucial importance for Europe, now more than ever. First, for recovery. The COVID-19 outbreak has weakened the European economy and undermines the future prosperity of European citizens and business. This strategy proposes a path forward that is cost effective, promotes well targeted investment in infrastructure, avoids stranded assets and leads to lower bills for businesses and customers. In short, it is key to accelerating our emergence from this crisis. Second, for climate neutrality. Energy system integration is essential if we want to reach our higher 2030 targets and climate neutrality by 2050. It enables a larger integration of renewables, the emergence of new fuels and a more circular approach to energy production and transmission.

Finally, a truly integrated energy system is vital for shaping Europe's global leadership in clean energy technologies. By leveraging Europe's existing strengths: an established leadership in renewable energy; a regional approach to system operation and infrastructure planning; liberalised energy markets and excellence in energy innovation and digitalisation.

Where we find ourselves now is far from where we need to be by 2050. To get there, both fundamental and far-reaching action is needed, urgently. The Clean Energy for all European's Package adopted in 2018-2019 lays the foundation for system integration and should be fully implemented. The new actions laid out in this communication will add the necessary scope and speed to move towards the energy system of the future in the context of the increased climate ambition and the legislative revisions for June 2021. The time to act is now.

Obviously, system integration will not be a one-size-fits-all process: despite a common objective of EU climate neutrality by 2050, EU Member States have different starting points. As such, Member States will follow different pathways, depending on their respective circumstances, endowments and policy choices, which are already reflected in the respective National Energy and Climate Plans (NECPs). This strategy offers a compass to direct these efforts in the same direction.

Citizens have a central role in system integration. This means that they should contribute to shape the implementation of this Strategy, using the Climate Pact as well as other existing citizen fora to advance the system integration agenda.

With this document, the Commission invites the Council, the Parliament, other EU institutions and all stakeholders to focus on how to take forward energy system integration in Europe. It intends to invite interested parties to debate in a **large dedicated public event** at the end of this year and to launch **public consultations and impact assessments to inform the preparation of the follow-up proposals foreseen for 2021 and beyond**.